Investigating the Effectiveness of Technology-Based Alliances: Patterns and Consequences of Inter-Firm Cooperation

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Technology-Based Alliances: Patterns
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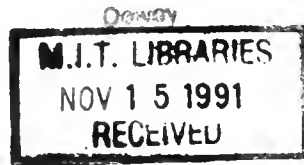Cooperation

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Abstract

In the last two decades, an increasing number of scholars have begun to study inter-firm cooperation to better understand organizations and their environments. A number of theories have evolved, drawing on such diverse fields as economics, sociology and organizational behavior. These theories variously argue that through such relationships organizations find resources, mimic other organizations, influence their own performance, or evolve as ecological systems. Empirical studies of these relationships have been few, and mostly limited to certain product sectors.

In this paper, I report the results of analyses using a comprehensive data set of inter-firm relationships (joint ventures, technology transfers, licenses and alliances). The information about the relationships were collected from the Wall Street Journal Index (January 1985 – September 1990), and about publicly held US firms from the COMPUSTAT database. The firms that were not publicly held US firms were coded based on their country of origin. Results presented in the paper show that an overriding number of relationships involve a technology-based product or process and that pure marketing arrangements are very rare. In addition, the impact of several variables (e.g. time, country, and product sector) in the creation of these inter-firm relationships is assessed.

Key Words: *Inter-organizational Networks. Joint Ventures. Technology Transfer. Licenses. Network Theory. Resource Dependence. Corporate Strategy. Cooperation. Alliances. Inter-industry Comparisons. Longitudinal Analysis.*

As the opportunities and problems of a globalized economy have grown, so have the interests of scholars in related phenomena. One of the more immediate and interesting phenomena is the large number of relationships that the organizations seem to enter into among each other. This seems fairly new. In the past, most scholarly traditions studied organizations as fairly closed systems. When the analysis was at the level of the individual member, however, the scholars did notice interactions across firms that made a difference. Individuals who span organizational boundaries were found to affect performance, even without obvious formalized links, as was shown in the notions of gatekeepers (Allen, 1984), lead users (von Hippel, 1988), and, interlocking directorates (Allen, 1974; Mintz & Schwartz, 1981; Pennings, 1980).

But the *claim* is that the paradigm has changed. Organizations are formalizing relationships. They actively seek partners and enter into arrangements such as as joint ventures and strategic alliances. Further, they do not just seek a few dyadic relationships, but a whole series of relationships that safely entrench them in a protective network of relationships.

An active stream of inquiries, mostly theoretical, are now seeking to explain the new paradigm. They describe organizations as open systems, and put forth various explanations drawing on diverse fields as economics, sociology and organizational behavior. But empirical studies have been few, due to the inherent and severe difficulties associated with macro-level data. Consequently most of the theoretical constructs have remained untested.

The study reported in this paper is empirical, though the analyses at this stage are still exploratory. The fundamental research questions are the following. Do such inter-firm networks *really* exist? What are the *patterns* and *structures* of such networks if they do exist? Do they make any difference in the *performance* of the firms? It is too early in the cycle of creation of inter-firm relationships to find a definitive answer to the last question. We will, however, be able to cautiously surmise the general trends in performance from our data. While the analyses remain exploratory at this stage, by the completion of this study several theoretical constructs, will be rigorously tested.

The analyses are based on a comprehensive set of data that I collected on inter-firm relationships and the firms themselves. The data collection will be described in a later section. Using the dataset, I examined the general patterns of inter-firm networks. The results show the effects of several variables, such as time, product sector, and country. Also, I present the results of a closer investigation on the patterns of relationships of the most central firms in the network.

We first turn to a brief summary of the related research streams.

PREVIOUS WORK

Technology-based organizations usually form around a fairly specific knowledge-base. Thus, one sees the cyclic emergence of organizations that exploit, around a given time, a knowledge-base that has just become ripe for commercialization. Once it was the internal combustion engines, now it is the biotechnology. Once created, the organizations have to grow to survive, which depends on how successful it is in expanding its knowledge-base and its markets. All this is just tautological.

For long, it was assumed that an organization took on the task of expanding its knowledge-base and markets *single-handedly*. This has been implicit in all the main bodies of literature. The economists considered the firm as a black-box, and the sociologists thought of it as a closed system. There have been some discomforting issues such as employee turn over (Allen, 1984) and informal know-how trading (von Hippel, 1988; Schrader, 1989) that suggested "leakage" of the knowledge base across firms. Also, as mentioned before, there were the individual level organizational boundary spanning. But for these, the *unitary* view of organizations was probably an acceptable approximation and an organizations growth trajectory was dependent solely on the success of its *internal* efforts aimed at improving its technology and its markets.

But the unitary view of organizations has been steadily changing. Several

sociological and organizational theories based on an open system model of organizations have been emerging.[1] These theories variously argue that through such relationships organizations find resources (Aldrich, 1979; Aldrich, 1976; Aldrich and Pfeffer, 1976; Pfeffer, 1981), mimic other organizations (DiMaggio and Powell, 1983), influence their own performance (Koh and Venkatraman, 1990; McConnell and Nantell, 1985; Osborn and Baughn, 1990; Woolridge and Snow, 1990, etc.), or evolve as ecological systems (Hannan and Freeman, 1977; Hannan and Freeman, 1989; Fombrum, 1988). All these, it is further argued, in turn affect the competitiveness of firms and industries. Worthy of special mention in our context is the resource dependence theory which, more boldly than other organizational theories, allows proactive manipulation by an organization of its environment. Also, most of the "performance" studies have come from the fields of economics, finance and corporate strategy. Most of these examine the abnormal returns on the securities of two parent firms when they enter into a relationship.[2] Some synergistic benefits from the mutual dependence of the firms are hypothesized, and usually found.

Though the movement away from the unitary model of the organization has been steady and generally slow, a set scholars have already begun to strongly assert that reality indeed is far from a fuzzy non-unitary model, and that only a full-fledged *network* model can fully explain organizations and their behavior (Jarillo, 1988; Powell, 1990; Thorelli, 1986). In a network model, overlapping sets of organizations have mutual relationships that would give them great benefits from shared knowledge-bases and managed markets.

Evidence for all this has been scant. We next turn to describe the data and collection methods.

DATA

Most of the important scholarly contributions on inter-firm relationships so far has been theoretical in nature. Empirical research on large organizational systems has always been difficult. The data are difficult to collect, and once collected, they are usually too voluminous to handle. Worse, analyses are problematic due to difficulties in ruling out rival hypotheses. So, just as it has been until recently in fields like cosmology and astronomy, the *organization-environment* field too has been the happy stomping grounds for theoretical abstractions and little else. All the empirical efforts had to be limited in scope to make the data manageable.

All that is changing. Computers, electronic networks and the information revolution are altering the way in which the empirical research can be carried out. A large part the the data have to come from secondary sources. This is a matter of some concern for all of us schooled in the value of primary data. However, that still would be better than clever speculations.

The data used in this study came from public or commercial sources. Two important aspects about the data bears special mention. First, the data are very current. The data set includes inter-firm relationships for the period from January 1985 to September 1990. Second, the data are very comprehensive, not being limited to any industry, sector or region. The data collection and preparation were done electronically. Two types of data were collected. They are described below.

Data on Inter-Firm Relationships. The data on inter-firm relationships were collected from the announcements of such relationships in the Wall Street Journal Index. The index from January 1985 to September 1990 was searched elec-

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[1] See Scott (1987) for an excellent summary of the various theories.

[2] In these fields, performance in the securities markets are considered a good proxy for a broad band of performance measures such as profitability, compound growth rates, etc.

tronically for four key words: "joint venture," "technology transfer," "license," and "alliance." The abstracts that contained the keywords were collected. All the abstracts were later passed through an electronic filter. The electronic filter was created for two purposes. First, it would help in pruning the data of unwanted items. Second, it would convert the data into a format readable by the software used for the analyses. The electronic filter parsed the abstracts into the following fields:

1. Name of the Journal
2. Date
3. Companies in the Relationship
4. Additional Information on Companies
5. Nature of the Relationship: Joint Venture, Technology Transfer, License or Alliance.
6. Purpose of the Relationship
7. Amount Involved
8. Comment

After parsing, the filter presented to a user the original abstract as well as its corresponding parsed fields. The user was given the option to discard the item (i.e., not accept the datum), accept it as parsed by the electronic filter, or accept it after modifying the fields. A group of undergraduate research assistants pruned the original data using the electronic filter.

Finally, the data on inter-firm relationships were further processed as follows. The company names were squared with those from the COMPUSTAT database (see next paragraph). Also, multiple announcements about the same relationship were aggregated to record only a single relationship.

Data on Firms. The data on public US companies were gathered from COMPUSTAT, a commercially available database. Information on the firms' basic attributes (product class, employees, R&D spending, assets, etc.), and performance (compound growth rates, profitability, abnormal returns, bond ratings, etc.) were collected.

RESULTS OF EXPLORATORY ANALYSES

The various exploratory analyses reported below were carried out to take a systematic look at the patterns and nature of inter-firm relationships. The data set contains information on more than 1700 relationships by 1562 organizations. Various effects are explored: the temporal patterns of the growth of inter-firm relationships, the "country" effects, variation in the creation of the relationships as a function of the product classification of the parent companies, etc. Firms that have the largest number of these relationships are also identified.

Note: *Wherever the frequency of relationships in 1990 is shown, note that data from the first nine months of the year only have been used.*

Overall Temporal Effects

In Figure 1 we see the frequency of the inter-firm relationships as a function of time. The darker bars represent *all* relationships. The figure shows that while there is some cyclicity in the creation of these relationships (note the low point
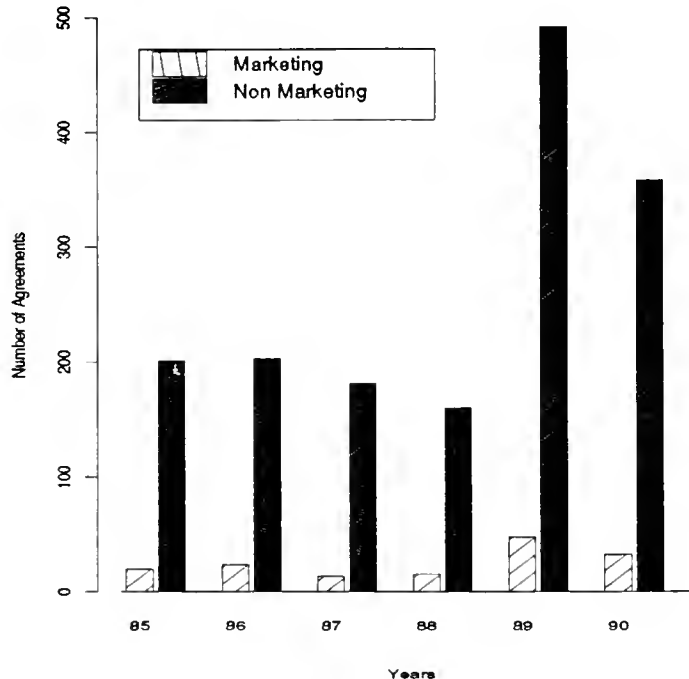
Figure 1: Frequency of Inter-Firm Relationships as a Function of Time

in 1988, an election year in the US, and the spurt afterwards), if we consider the *cumulative* effect, they have been greatly increasing over time. It is perhaps the yearly relative magnitude of this cumulative effect that has persuaded some writers in the field to propose the formation of *networks of firms.*

In Figure 1 we also have the frequency of relationships that were formed purely for marketing purposes (lightly hatched bars).[3] We see that such purely market-based relationships are very few in comparison. All other relationships have *both* technology and market components in some combination. It is also reassuring to note that, though the relative magnitudes are very different, the distributions are nearly identical.

Effects of Globalization

It has been argued that much of the impetus for the increase in inter-firm relation-ships has come from the globalization of the economies. It is reasonable, therefore, to expect increasing participation by foreign firms in cooperative relationships of various kinds. We turn to examine the relationships between US and foreign firms.

In Figure 2 we see a significant growth in the relationships with firms from four European countries: Germany, United Kingdom, France and Switzerland. These countries in Europe have the largest number of relationships with American firms. The dramatic growth of German relationships is particularly noteworthy.

Such inter-firm cooperation is not limited to industrialized western countries. As Figure 3 shows, links with communist, or formerly communist, countries have

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[3]An example of this kind of relationship would be, say, two large airline firms having an alliance to help each other in their respective regional markets.
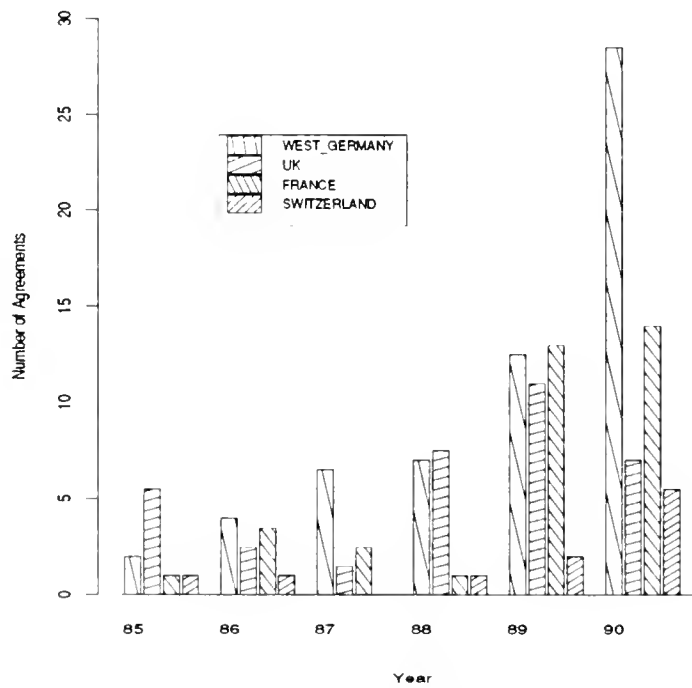
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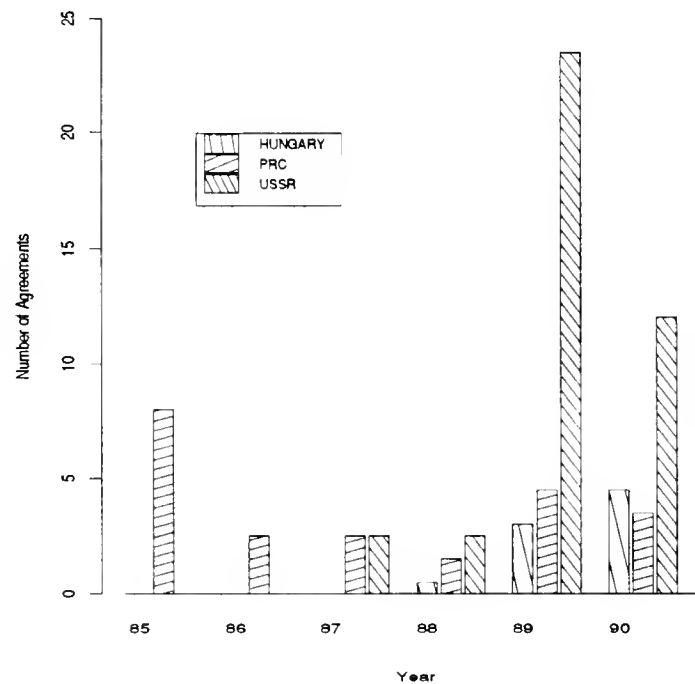Figure 2: Frequency of Relationships Among Firms From the US and Four European Countries as a Function of Time

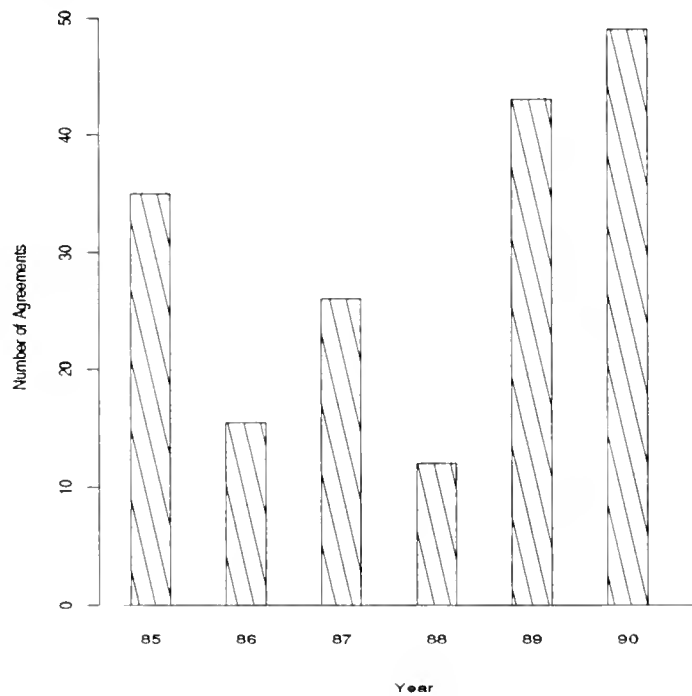Figure 3: Frequency of Relationships Among Firms From the US and Former and Current Communist Countries as a Function of Time

Figure 4: Frequency of Relationships Among Firms From the US and Japan as a Function of Time

also been on the ascendant. The relationships with China have been fairly steady, though perhaps have suffered some recent decline. The lagged-effect of Perestrioka seems to be reflected in the relationships with the USSR. The relationships with Hungary have been steadily increasing.

Figure 4 showing relationships with the Japanese firms would be of great interest to the reader, though the increasing trend would come as no surprise. Unmistakably, the Japanese cooperative ventures, on the average, have been growing, and constitute the single largest component of US firms' foreign relationships.

Effect of Product Sectors

Earlier, we noted that the few empirical studies on inter-firm cooperation were limited to certain product sectors. Generalizability of these studies is a serious problem. As the first step, it is useful to understand the distribution of these relationships as a function of the product class. With this in mind, their frequencies were calculated as a function of the three digit primary Standard Industrial Classification (SIC) Code of each parent. The results, for SIC codes with more than 20 relationships, is shown in Figure 5.[4] The legends on the bars of the histogram are explained in the table attached to the figure.

The sectors which are highly active with respect to these relationships seem to be either technologically on the "cutting-edge" (eg. Drugs and Telephone Communication) or in serious trouble, and seeking "new" technologies (eg. Motor Vehicles and Commercial Banks). While the reader may not be surprised by the sectors identified, it will take much more careful analysis to explain why the cooperative activities among firms are the largest in these specific sectors. Note, for example, only *"Commercial Banks"* is represented from the service industry. In any case, it is clear that inter-firm cooperative activities are not uniform across sectors.

Rank Ordering Network Participants

For studying relationships among entities, it is useful examine the rank ordered frequency of the entities as a function of the number of their relationships. For the firms we study, this is shown in Figure 6. There are theoretical reasons that make these distributions interesting. For one, such natural distributions are expected to follow a $\frac{1}{n^2}$ pattern (George, 1989; Lotka, 1926; Simon, 1957; Zipf, 1949). Since in fact it does, the figure provides indirect confirmation about the validity of our data. Also, the properties of the distribution suggest how centralized and/or diffused the underlying network is.

Our distribution suggests two very important points. A very large fraction of the firms (88% — 1378 firms) has three or less relationships. And, only very few (0.03% — 41 firms) have 10 or more relationships. Notwithstanding blanket theoretical predictions, if inter-firm networks do exist, they seem to exist only among very few firms.

To investigate this further, the firms were classified into three groups: "High," with more than 10 relationships, "Medium," with 4–9 relationships, and "Low" with 1–3 relationships. This classification divides the underlying matrix of relationships into nine parts. The density of relationship for each part was calculated. The results are shown in Table 1. These numbers also confirm that inter-firm cooperative relationships are mostly controlled by a few central firms.

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[4]Other SIC codes were pruned just to make the histogram visually manageable.

	SIC	Sector Name
A	280	Chemicals & Allied Products
B	282	Plastic Synthetic Material
C	283	Drugs
D	291	Petroleum Refining
E	357	Computer & Office Eqpmt
F	360	Electrical, Oth Elec Eqpmt
G	371	Motor Vehicles
H	372	Aircraft and Parts
I	386	Photographic Eqpmt & Supply
J	481	Telephone Communication
K	602	Commercial Banks
L	873	Research,Development,Testing

3 Digit SIC Codes with Number of Agreements Greater Than 20
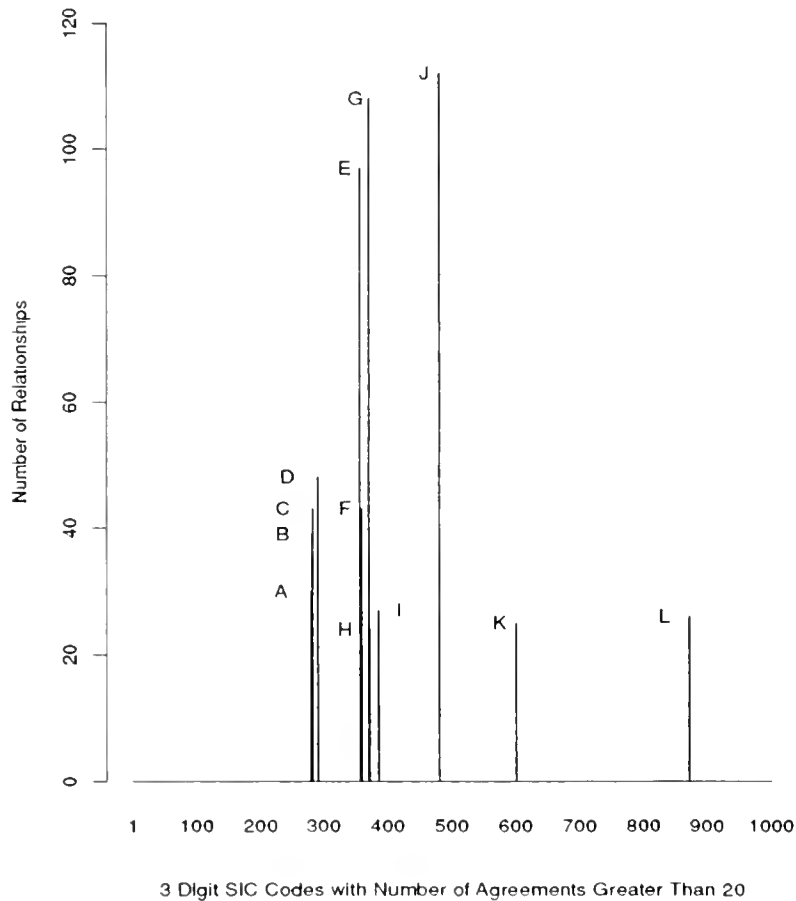
Figure 5: Frequency of Relationships as a Function of Product Class

Note:
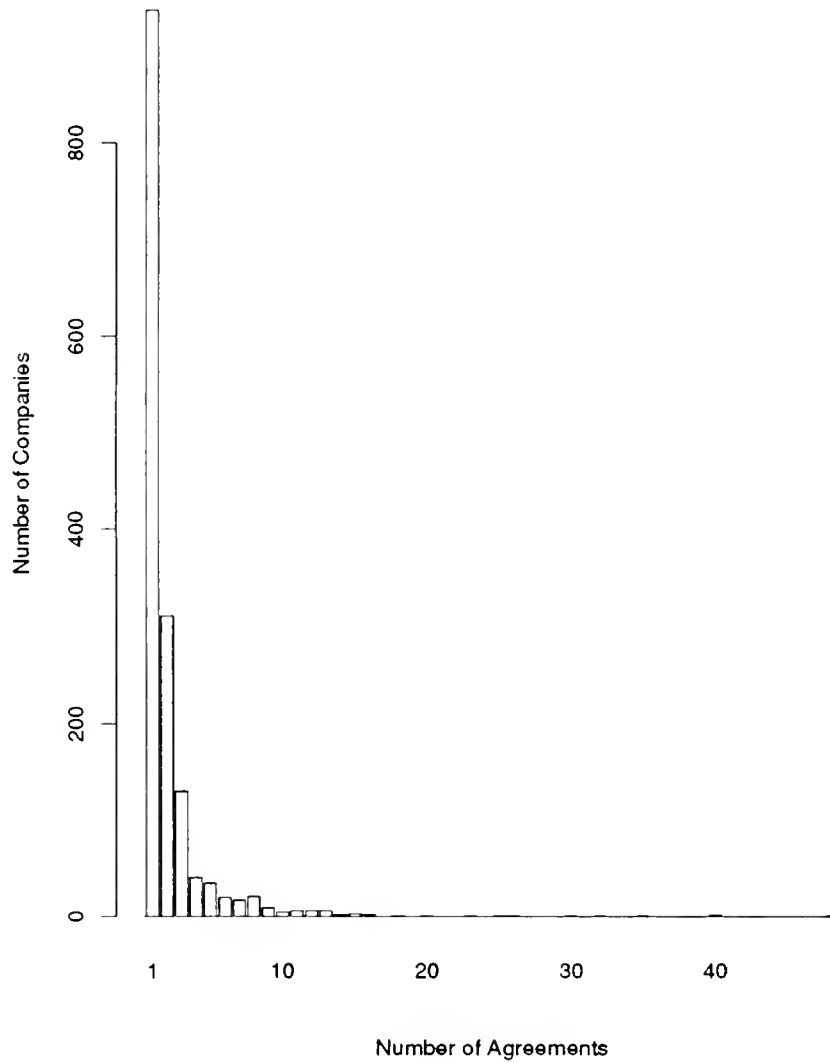*To avoid clutter, only SIC Codes with more than 20 relationships are represented in the figure.*

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Figure 6: Rank Ordered Frequency of Firms as a Function of the Number of Their Relationships

Table 1: Comparison of Densities of Interfirm Networks

Densities of Interfirm Networks			
Sub-Networks Classified by Firm's Number of Relationships			
	HIGH $n = 11$	MEDIUM $n = 143$	LOW $n = 1378$
HIGH	0.14	0.034	0.005
MEDIUM	0.034	0.016	0.002
LOW	0.005	0.002	0.0007

NOTE
HIGH: More than 10 relationships
MEDIUM: 4–9 relationships
LOW: 1–3 relationships

SUMMARY AND CONCLUSION

The exploratory analyses showed that the number of inter-firm relationships has been increasing over time. The effect of globalization was also very clear. The number of foreign firms entering into relationships with US firms has been rising, with Japanese firms leading the pack. However, it was found that only in certain product sectors that any significant number of relationships are created. Also, on closely examining the matrix of relationships, a large number of dyadic relationships were found, but network-like behavior was limited to a very small number of very large firms. Among these were some highly successful Japanese conglomerates, and large US firms seemingly responding to duress.

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